A satellite approach for estimating regional land surface energy budget for GCIP/GAPP

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[1] Conventional observations cannot provide information on land surface energy fluxes, or information for land surface parameterizations, on a global or regional scale. In this paper, a satellite approach for estimating regional land surface energy budget is developed and implemented to the Mississippi River Basin, which serves as the focus of the World Climate Research Program Global Energy and Water cycles Experiment (GEWEX) Continental Scale International Project (GCIP) and GEWEX Americas Prediction Project (GAPP). The objective of this study is to evaluate the potential of using recently available satellite information to advance current capabilities in determining regional land surface energy budget. The primary forcing parameters in this approach, namely, surface shortwave radiation and skin temperature, are derived from the Geostationary Operational Environmental Satellite (GOES) observations, using inference schemes that are operationally executed at the National Oceanic and Atmospheric Administration National Environmental Satellite Data and Information Service (NESDIS). Shortwave radiation is used to define the absorbed energy at the surface. Diurnal variation of skin temperature is used to define the surface energy partitioning. The real-time NESDIS GOES product covers the continental United States (25°–53°N, 67°–125°W), at a 0.5° spatial resolution and an hourly temporal resolution. Atmospheric conditions of near-surface air temperature, humidity, and wind speed are obtained from the NOAA National Centers for Environmental Prediction (NCEP) Eta model output. A 1-year simulation (May 1997 to May 1998) of the Mississippi River Basin surface energy budget is performed. Model inputs of shortwave radiation and skin temperature, and resulting latent and sensible heat fluxes, are evaluated on various spatial and temporal scales. On a local scale, over the 1-year study period, the RMS difference between estimated and observed monthly shortwave fluxes and latent and sensible heat fluxes are 32, 21, and 20 Wm^{-2}, respectively. On a regional scale the estimated summertime energy fluxes are of similar pattern and same order of magnitude as the corresponding reanalysis results from NCEP and National Center for Atmospheric Research. *INDEX TERMS:* 3322 Meteorology and Atmospheric Dynamics: Land/atmosphere interactions; 3360 Meteorology and Atmospheric Dynamics: Remote sensing; 1818 Hydrology: Evapotranspiration; *KEYWORDS:* surface energy budget

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1. Introduction

[2] Understanding the variability of regional and global energy and water budgets is among the goals of the World Climate Research Programme (WCRP) Global Energy and Water Cycle Experiment (GEWEX) [*World Meteorological Organization* (*WMO*), 1988]. As part of the overall scientific strategy of GEWEX, the GEWEX Continental-Scale International Project (GCIP) and the follow-up GEWEX Americas Prediction Project (GAPP) are established to bridge the gap between small-scale (appropriate for modeling the land process), and large-scale (practical for modeling the climate system) studies, in order to enhance the prediction capability of the regional and global energy and water budgets. The Mississippi River Basin is selected as

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the focus of the GCIP/GAPP activities because of its extensive meteorological and hydrological observation network [*International GEWEX Project Office* (*IGPO*), 1994; *Lawford*, 1999].

5. Summary and Discussion

[36] In this study, an approach is developed for estimating SEB on a regional scale, using recently available satellite-based information. Most of the input parameters in this approach, for example, surface SW fluxes and skin temperature, near-surface atmospheric temperature, relative humidity and wind speed, are obtained from the operational NESDIS-UMD GOES SRB product and NCEP Eta model.

[37] For regional and global SEB studies, there is a need to utilize standardized measurements covering all parts of the domain. Satellites are ideal for providing such information. This study evaluates the quality and limitation of the NESDIS-UMD GOES SRB product, and establishes concepts for using this product in relevant researches. Lessons learned from evaluating the satellite-estimated SEB components using widely accepted ground observations (ARM and SURFRAD) are documented.

[38] The fundamental differences between this satellite approach and the more sophisticated land surface schemes can be summarized as follows. The sophisticated schemes [*Dickinson*, 1984; *Mahrt and Pan*, 1984; *Sellers et al.*; 1986; *Xue et al.*, 1991; *Koster and Suarez*, 1992] use soil and vegetation types to initialize a large number of the soil and vegetation parameters. Evaporation from soil and evapotranspiration from vegetation are parameterized separately. Tests of spatial aggregation procedures are critical to properly represent the grid values over a sub-grid-scale heterogeneous surface [*Arain et al.*, 1997]. Besides, when applying satellite information to an area that has heterogeneous vegetation within a single satellite grid, caution is needed since each portion of a given satellite grid may have different surface characteristics, such as vegetation type and albedo. Procedures of disaggregating a grid-averaged satellite estimate, such as SW flux, to each subgrid portion, must be evaluated. The satellite approach used in this study simplifies the soil and vegetation initialization. Clear-sky and all-sky SW fluxes and clear-sky skin temperature are estimated from the same satellite observing system. The primary impact of soil moisture and vegetation on SEB, namely, regulating the surface energy partitioning, is implicitly incorporated in the daytime surface temperature variation. Ground and vegetation are treated as a combined unit. Satellite-estimated SW fluxes and skin temperature are reasonable representations of grid area averages over this combined ground-vegetation surface. Model performance relies on the quality of the satellite estimates, instead of on the prescribed values of the soil and vegetation parameters. Once the satellite-estimated surface heating rate is reproduced in the model, a realistic surface energy partitioning can be obtained.

[39] Results from a 1-year simulation (May 1997 to May 1998) are analyzed on various spatial and temporal scales. On a local scale, model inputs of satellite-estimated surface SW flux and skin temperature, and model results of R_n, LE, and H, are evaluated against ground observations. The differences between modeled and observed energy fluxes are of the same order of magnitude as the observational uncertainties [*Wesely et al.*, 1995; *Charlock and Alberta*, 1996; *Chen et al.*, 1996; *Berbery et al.*, 1999; *Pinker et al.*, 2003]. On a regional scale the relationship between the surface energy partitioning and the corresponding vegetation type is analyzed. Results show that, in summertime, the ratio of LE/R_n is much higher in areas consisting of croplands and forests as compared to grasslands. As suggested by *Pitman* [1994], croplands have higher soil water content in the growing season, and forests have higher leaf area index; and both encourage higher ET. The distributions and magnitudes of simulated R_n, LE, and H over the Mississippi River Basin are consistent with the corresponding NCEP-NCAR reanalysis results, and reveal a reasonable relationship with the vegetation heterogeneity. Results for winter are not evaluated on a regional scale because, because of snow and cloud contamination, the number of samples of the satellite-estimated skin temperature is not enough for obtaining a monthly heating rate analysis for a significant number of grid points in higher latitudes. If another skin temperature product (which can include cases of snow and cloudy conditions) becomes available in the future, it would provide an opportunity to extend this implementation to various conditions on various timescales.

[40] Previous studies indicated that, although being initialized with identical values of the soil and vegetation parameters, and being driven with identical atmospheric forcing, simulations from different land surface schemes still exhibit a large degree of scatter [*Henderson-Sellers et al.*, 1993; *Chen et al.*, 1996; *Betts et al.*, 1997]. For evaluation and assessment, building observation networks that can provide long-term, large-scale, qualitative observations, is essential. However, it is worth noting that the "observed" LE and H are not directly measured, but are estimated from other meteorological measurements such as air temperature, humidity, and wind speed. The observational uncertainties are considerable, since small errors in the meteorological measurements may produce large errors in heat flux estimates, and therefore the observations may not necessarily close the energy balance equation as the models do. There is also a scale inconsistency between the spatial and temporal resolutions of the satellite observations and the ground observations. In evaluating a modeled SEB on a regional or global scale, a qualitative representation of the large-scale climate features is of value.

[41] This paper demonstrates that with the available satellite data, a regional-scale SEB can be estimated using this satellite approach. It provides an opportunity to extend our current capability of modeling and assessing the surface-atmosphere interaction, and its role in regulating weather and climate. Future work involves incorporating the satellite-estimated surface SW fluxes, skin temperature and heating rate within the framework of the ongoing project of the Land Data Assimilation System (LDAS) [*Mitchell et al.*, 2003] to achieve a more comprehensive understanding of regional and global-scale land surface energy and water cycles.